Managing delta smelt entrainment at the Banks and Tracy Pumping Plants

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**Reasons for managing delta smelt entrainment**

Delta smelt (smelt) are entrained at the Banks Pumping Plant (Banks) and the Tracy Pumping Plant (Tracy). Adults can be entrained as early as November and as late as June. Larvae and juveniles can be entrained as early as February and as late as August. For both life stages, most entrainment is confined to months well within those ranges.

I estimated the percentage of each life stage entrained (Miller 2005a, Miller 2005b). I was not able to find correlations between any measures of entrainment of either life stage, together or separately, and the subsequent Fall Midwater Trawl (FMWT) sub-adult abundance, the primary index of smelt abundance. This is not to say that entrainment can have no effect on subsequent abundance. Indeed, if virtually all of either life stage were entrained, subsequent abundance would undoubtedly be affected. However, entrainment as a percentage of either life stage has not been nearly that high.

If the number of smelt in the winter and spring, albeit small, is large relative to what can be sustained by subsequent conditions, it is possible that entrainment has no effect on subsequent abundance. It is also possible that entrainment is having some effect on subsequent FMWT sub-adult abundance. However, the dominant effect on sub-adult abundance in the fall

is prey density in areas where smelt occur in the summer, after most entrainment has occurred (Miller 2005c). This prey density effect is apparently so large relative to the effect, if any, of typical entrainment levels that correlations cannot be found between sub-adult abundance and previous entrainment.

It is possible that entrainment of smelt prey affects prey density in key smelt–prey co–occurrence areas in the summer. This seems unlikely given the distance of these areas from Banks and Tracy and the growth rates of prey species. According to Mecum (Mecum 2005) prey density in the areas of smelt–prey co-occurrence is much more likely to be determined by prey growing there rather than migrating from 40+ miles away, where they might otherwise have been entrained.

On the other hand, smelt are a listed species. Because it has been assumed that smelt entrainment affects subsequent abundance, their "take" or entrainment at Banks and Tracy is managed. In addition, last year's abundance levels were the lowest yet recorded. This year's population is faring no better. This creates additional pressure to manage smelt entrainment in spite of the fact that data do not show a correlation between entrainment and subsequent abundance.. The question is: On what basis should smelt entrainment be managed?

**The basis of managing smelt entrainment**

Since its listing more than a decade ago, management of smelt entrainment has been based on the assumption that entrainment significantly affected subsequent abundance. There are no reliable data to support this assumption. Within the range of entrainment that has occurred since the listing of smelt, entrainment effects on subsequent abundance cannot be detected. Therefore, a reasonable approach would be to manage entrainment so as not to exceed past levels. A somewhat more conservative approach would be to manage entrainment at levels for which, based on past years' data, subsequent high abundance levels occurred.

The following principles might be used to manage smelt entrainment:

- Adult and larval-juvenile entrainment should both be managed.
- Management should keep entrainment below target levels, expressed on a population-effect basis, namely, as a percentage of the adult and larval-juvenile populations or a convenient surrogate for this percentage.
- Target levels should be chosen so they don't rule out the possibility of subsequent high abundance.
- Because of the lack of correlation of entrainment with subsequent abundance, strict compliance with the target levels is not necessary. The target level is only an indicator. The data do not provide justification for making this indicator a mandatory requirement.

- The management protocol should allow for real time adjustment of export rates (and barrier operation if necessary) to stay within target levels.

**Managing adult entrainment**

Relevant relationships

- Approximate average adult entrainment distribution by month over the last 12 years is shown in Table 1.
- Monthly adult salvage varies with the product of monthly export rate and the number of smelt east of Franks Tract (as estimated by Miller from Kodiak Trawl data) (Miller 2005d) as shown in Figure 1.
- The population of adult smelt estimated from the February Kodiak Trawl is related to the previous FMWT abundance index as shown in Figure 2 (Miller 2005e).
- The average ratio of adult population in February to that in March is about 1.5 (miller 2005d). If this ratio reflects usual mortality of adults, it would also approximate the ratio of January to February and December to January adults.
- Relationships between the FMWT index and subsequent percentage adult entrainment, adult salvage/Kodiak population, and adult salvage/previous FMWT are shown in Figure 3. Kodiak populations prior to 2002 were estimated using the relationship in Figure 2. Dashed vertical lines on each graph in Figure 3 show values below which high subsequent FMWT abundance indices occurred.

Adult entrainment could be managed based on percentage adult entrainment, estimated as described by Miller (Miller 2005a). However, this method involves the uncertainties of louver efficiency and prescreen mortality at Banks and Tracy Pumping Plants. To avoid concern over these uncertainties, adult salvage/previous FMWT could be used to estimate entrainment, as in the USFWS/DFG Delta Smelt Risk Assessment matrix.

Steps in managing adult entrainment

1. At the end of November, choose an adult salvage target at or less than the dashed vertical line in the bottom graph of Figure 3. Use the first three months of the FMWT to estimate what the final FMWT will be.
2. From Table 1, estimate the expected monthly distribution of this target adult salvage.
3. Use the estimated final FMWT and the relationship in Figure 2 to estimate Kodiak February adult population. December adult population can be estimated as approximately 3 times the February population.*
4. Use the percentage distribution from the November FMWT in combination with the estimated Kodiak adult population to estimate the number of adult smelt east of Franks Tract.
5. Estimate the target export rate for December from Figure 1.
6. At the end of December, repeat the process, this time using the completed FMWT. The January Kodiak population is approximately 1.5 times the February population, which can be estimated using the

relationship in Figure 2. Target adult salvage for January can be estimated from Table 1 and adjusted depending on whether the actual December adult salvage was above or below the December target.

7. Repeat the process at the end of January, this time using actual Kodiak January population and adjusting target adult salvage to reflect actual adult salvage in December and January.
8. Repeat the process at the end of February and March, using actual Kodiak estimates of population and distribution.

Summary

This process would have resulted in export curtailments to control adult smelt entrainment in 2003 and 2004, but not in other years.

Management of adult entrainment must also consider the possibility that higher salvage values observed at higher export rates result from lower mortality rates in or near the export facilities. Higher export rates presumably reduce the residence time and, therefore, the mortality of smelt because they have less time to die naturally and are less exposed to predators before they enter the export facilities. This suggests that higher salvage just counts smelt that would have died in the southeastern Delta anyway but had less time to do so before entering the export facilities when exports are high.

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* Ideally, Kodiak trawls would be carried in November and December to better define the distribution of smelt and to estimate the population.

There are two reasons not to be alarmed about adult entrainment. The most important one is that it apparently makes little or no difference to subsequent adult abundance, primarily because of the dominant effect of summer smelt-prey co-occurrence. The second reason is that higher salvage in part just reflects lower mortality near the export pumps.

**Managing larval-juvenile entrainment**

Background

As with adult entrainment, no relationship has been found between larval-juvenile entrainment and subsequent adult abundance. This is due to the dominant effect of summer smelt-prey co-occurrence, which happens after larval-entrainment. Attempts to manage larval-juvenile entrainment should reflect the fact that within limits of what has occurred in the past, management is likely to have little or no effect on subsequent adult abundance.

If larval-juvenile entrainment is managed, it cannot be based on salvage for several reasons. Larval smelt are not counted for salvage. No juveniles are counted until they reach 20 mm in length. The population of larval-juvenile smelt is not estimated and probably cannot be; they hatch over several weeks, numerous sizes are present at the same time, and larvae and small juveniles cannot be sampled efficiently.

However, assuming the 20 mm survey estimates the relative distribution of smelt and that larval-juvenile smelt behave more or less as neutrally buoyant

particles, the percentage of larval-juvenile population can be estimated using the Particle Tracking Model (Miller 2005b).

Relevant relationships

Figure 4 shows the relationship between the average percentage of larval-juvenile population in the southeast Delta and the average March-April Delta outflow. If March-April Delta outflow can be estimated, the percentage of smelt in the southeast Delta can be estimated.

Figure 5 shows the relationship between annual estimates of percentage larval-juvenile entrainment and the product of the percentage of smelt in the southeast Delta in April and May and average exports in April and May. Figure 6 shows the relationship between the hatching period, measured as the number of days between 2% and 98% hatch (Miller 2005b), and the day of the year when water temperature first reaches 12 degrees C at Goodyear Slough in Suisun Marsh. This station's 12-degree day of the year is the best predictor of the length of the spawning season. This graph can be used to predict the length of the spawning season. Constructing a cumulative normal distribution with 2% tails between the beginning and ending dates of the spawning season allows estimation of the fraction hatched for each 20 mm survey mid-date.

Figure 7 shows the FMWT index plotted against the percentage larval-juvenile entrainment. There is no correlation between these two variables. However, the graph does suggest that if percentage larval-juvenile

entrainment is below about 13%, subsequent high values of the FMWT index are not ruled out.

Steps in managing larval-juvenile entrainment

1. Estimate March-April Delta outflow and use Figure 4 to estimate the percentage smelt in the southeast Delta in April and May
2. Choose a target percentage larval-juvenile entrainment from Figure 7, presumably 13% or less.
3. From Figure 5 estimate a target export rate for April and May.
4. Use Figure 6 to construct a curve of fraction hatched vs. day of the year. Modify this curve as more temperature data become available.
5. As each 20 mm survey is completed, use the distribution of smelt from the survey, the Particle Tracking Model, and the fraction hatched curve to estimate the percentage larval-juvenile entrainment between that survey and the next.
6. The target percentage entrainment for each survey is about one fifth of the annual target (13% or less). If the percentage larval-juvenile entrainment for any survey is much above or below that value, adjust the export rate for the remaining surveys.

**Figure 1**
**adult salvage vs. delta smelt location and exports**

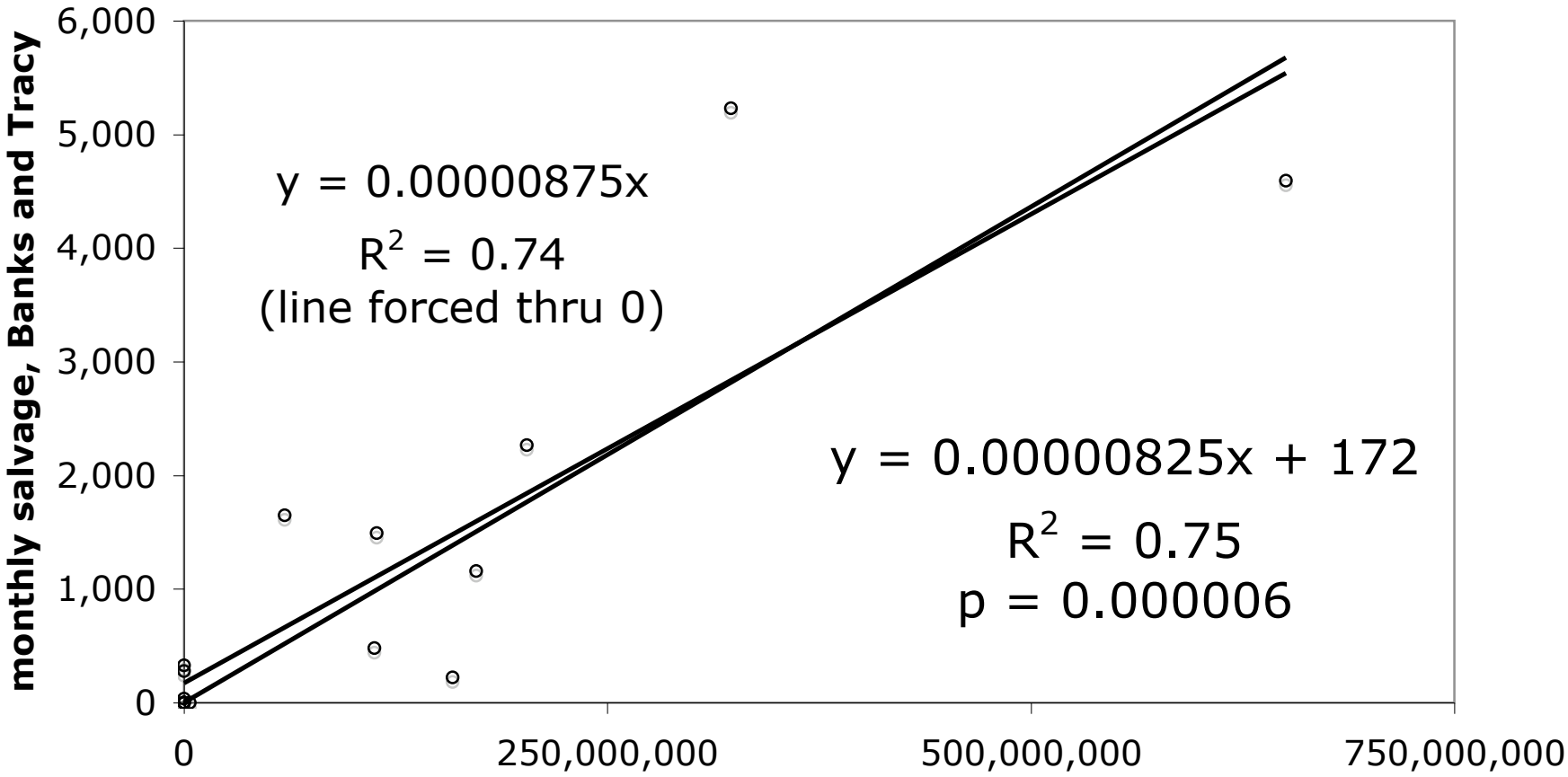


**Figure 2**
**February kodiak population vs. previous FMWT**

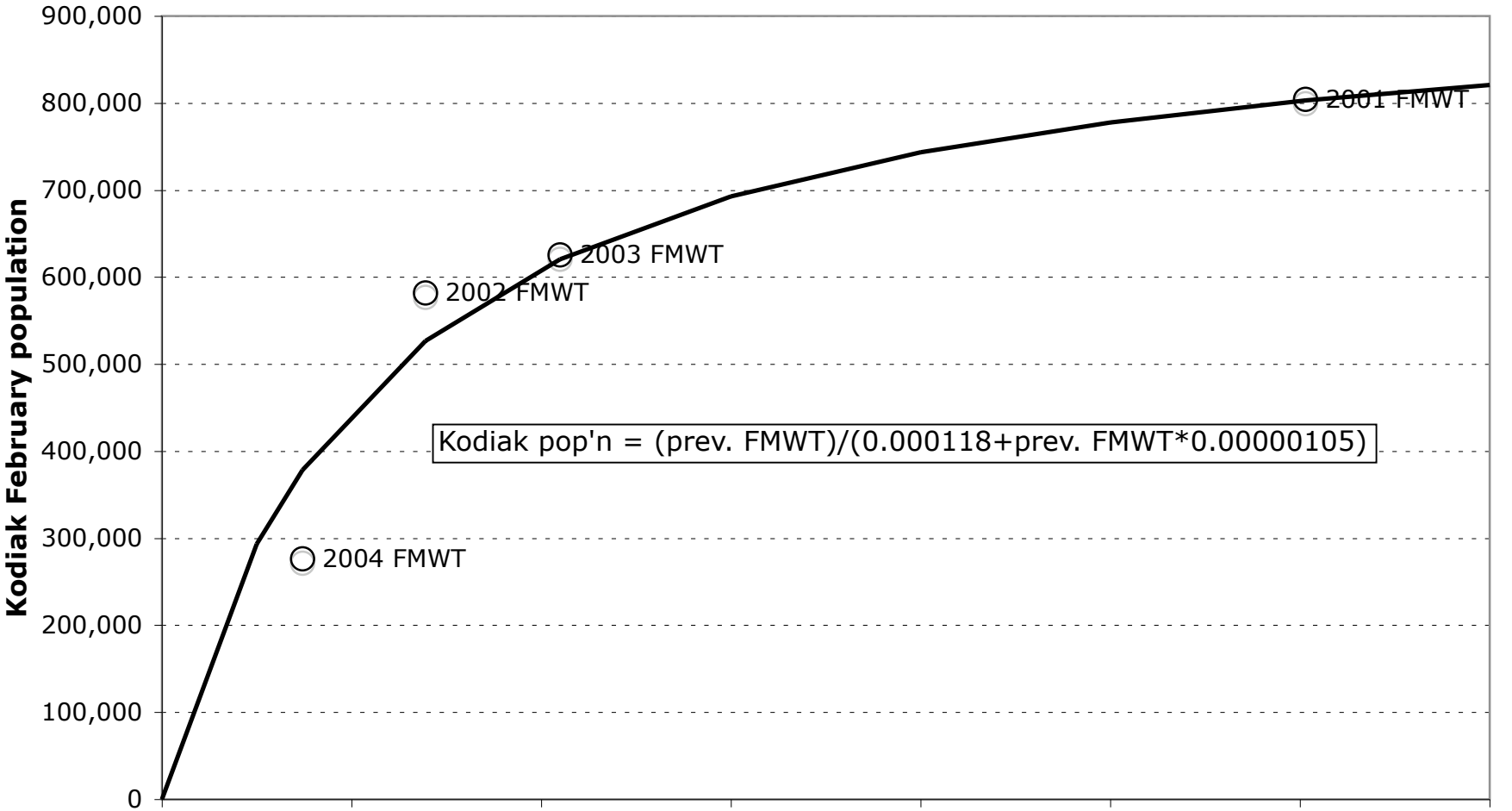
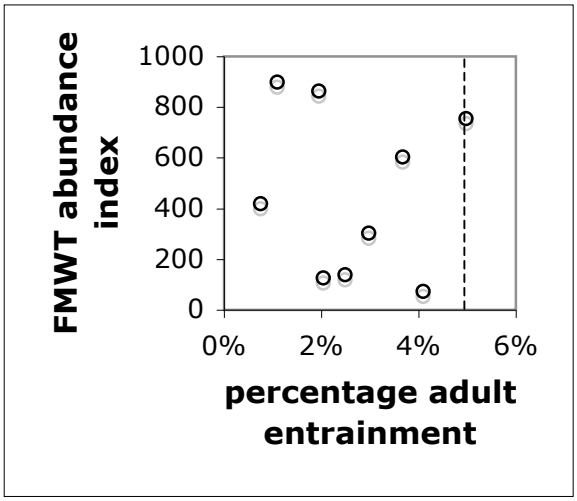
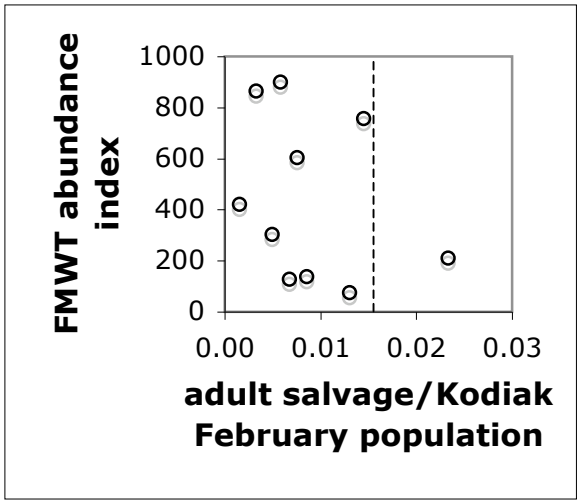
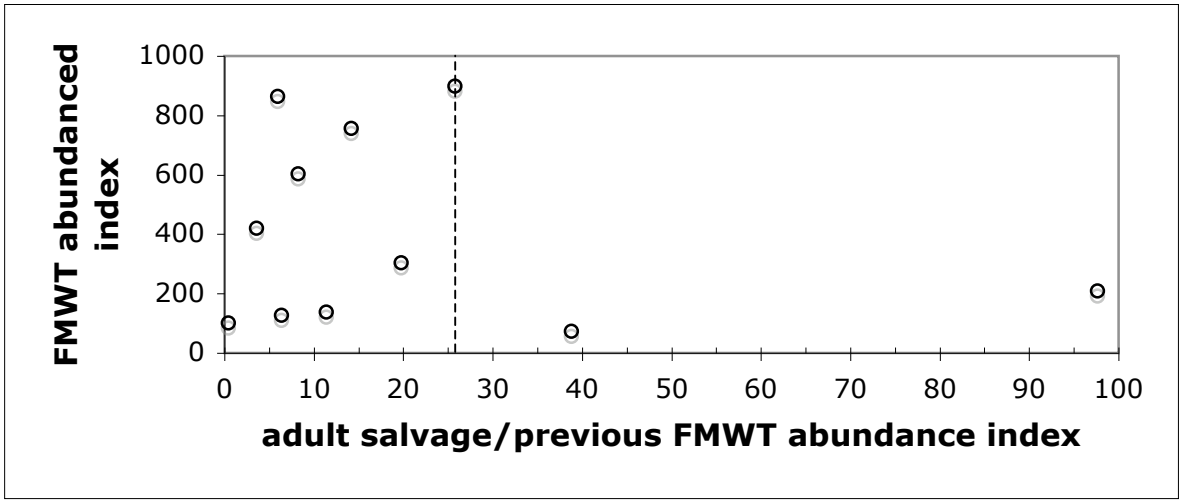


Figure 3

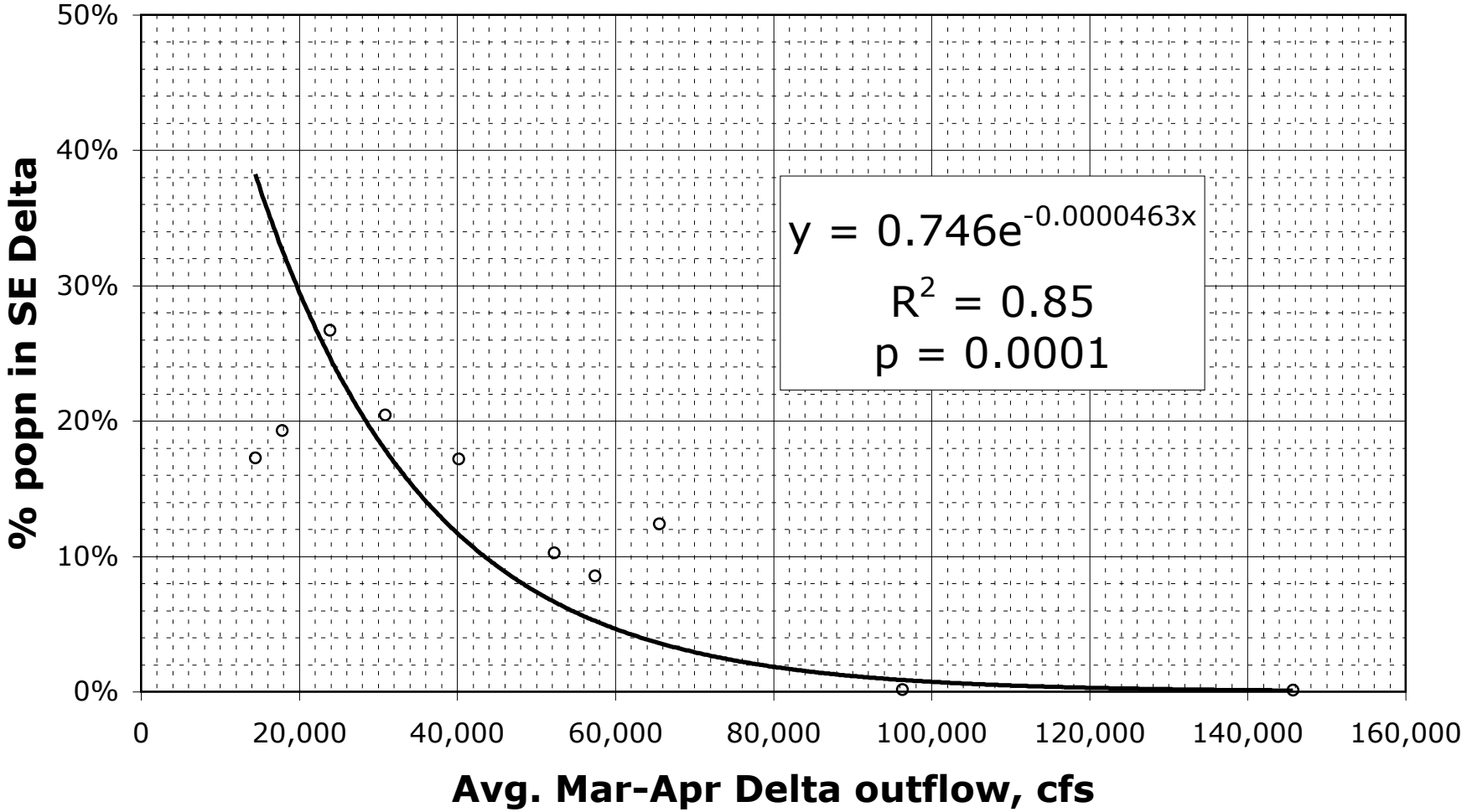
FMWT index vs. various measures of adult entrainment



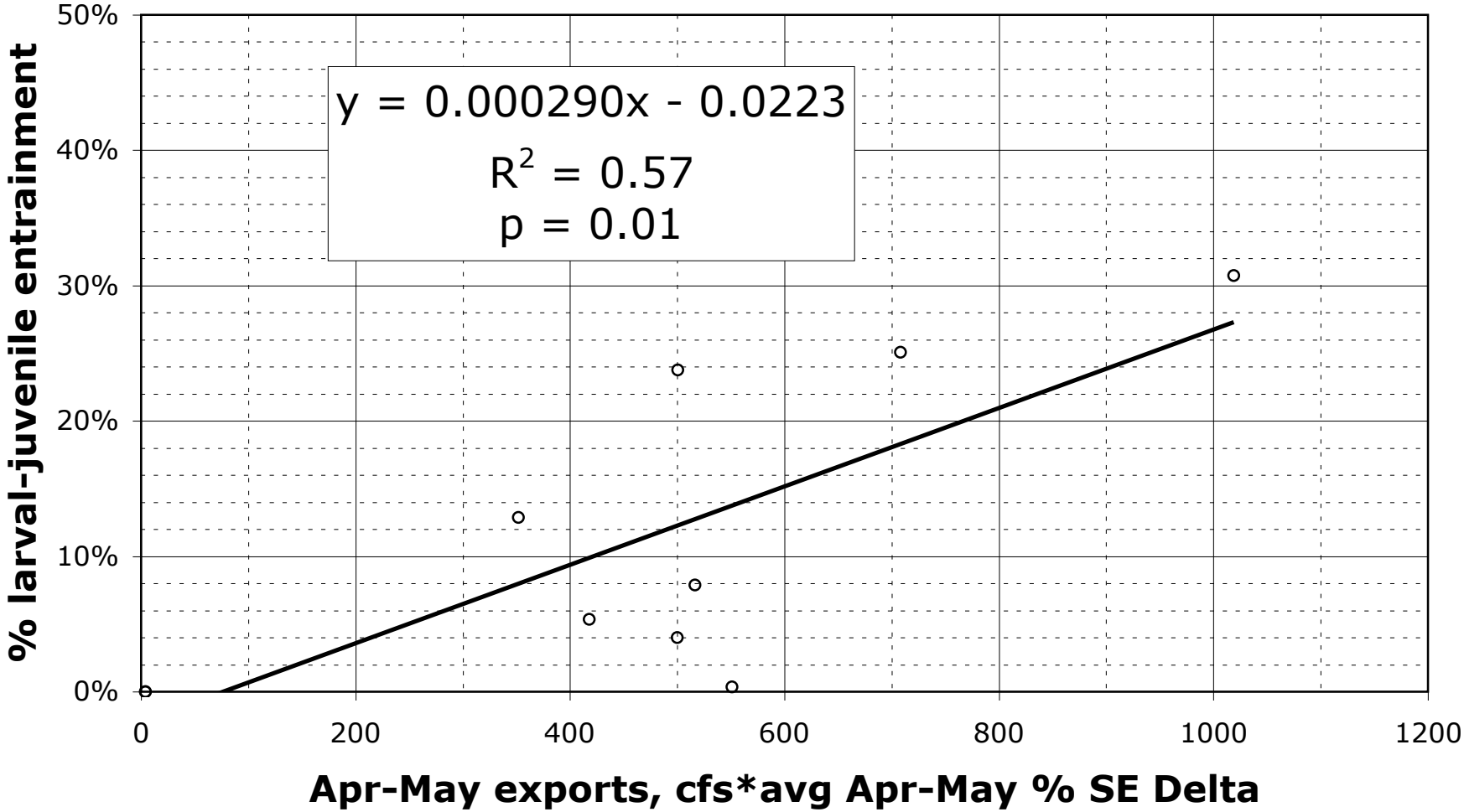



# Figure 4
# % larval-juvenile population in SE Delta



# Figure 5
# % larval-juvenile entrainment



# Figure 6
# length of spawning period vs. Goodyear Sl. 12-deg day

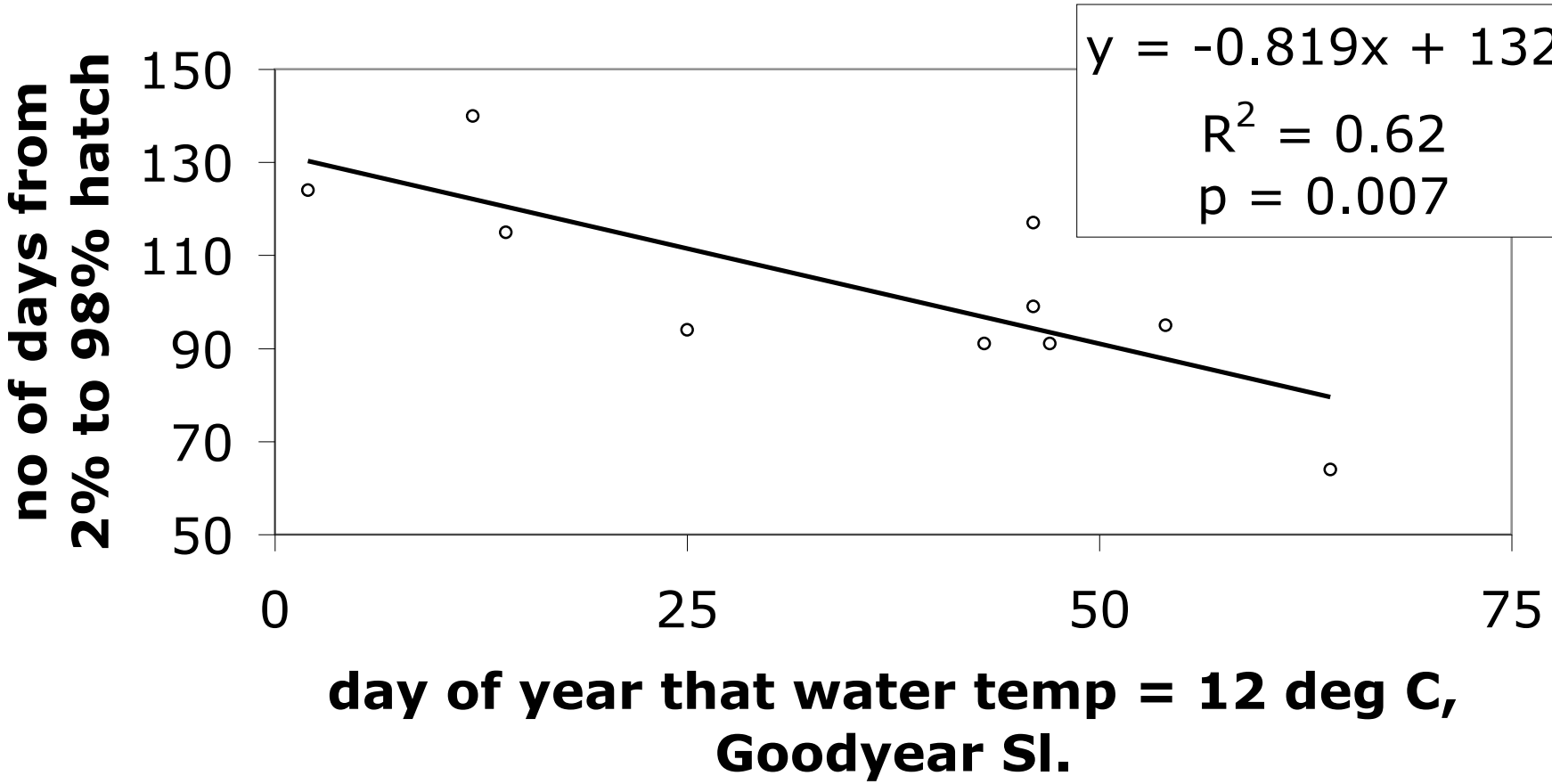
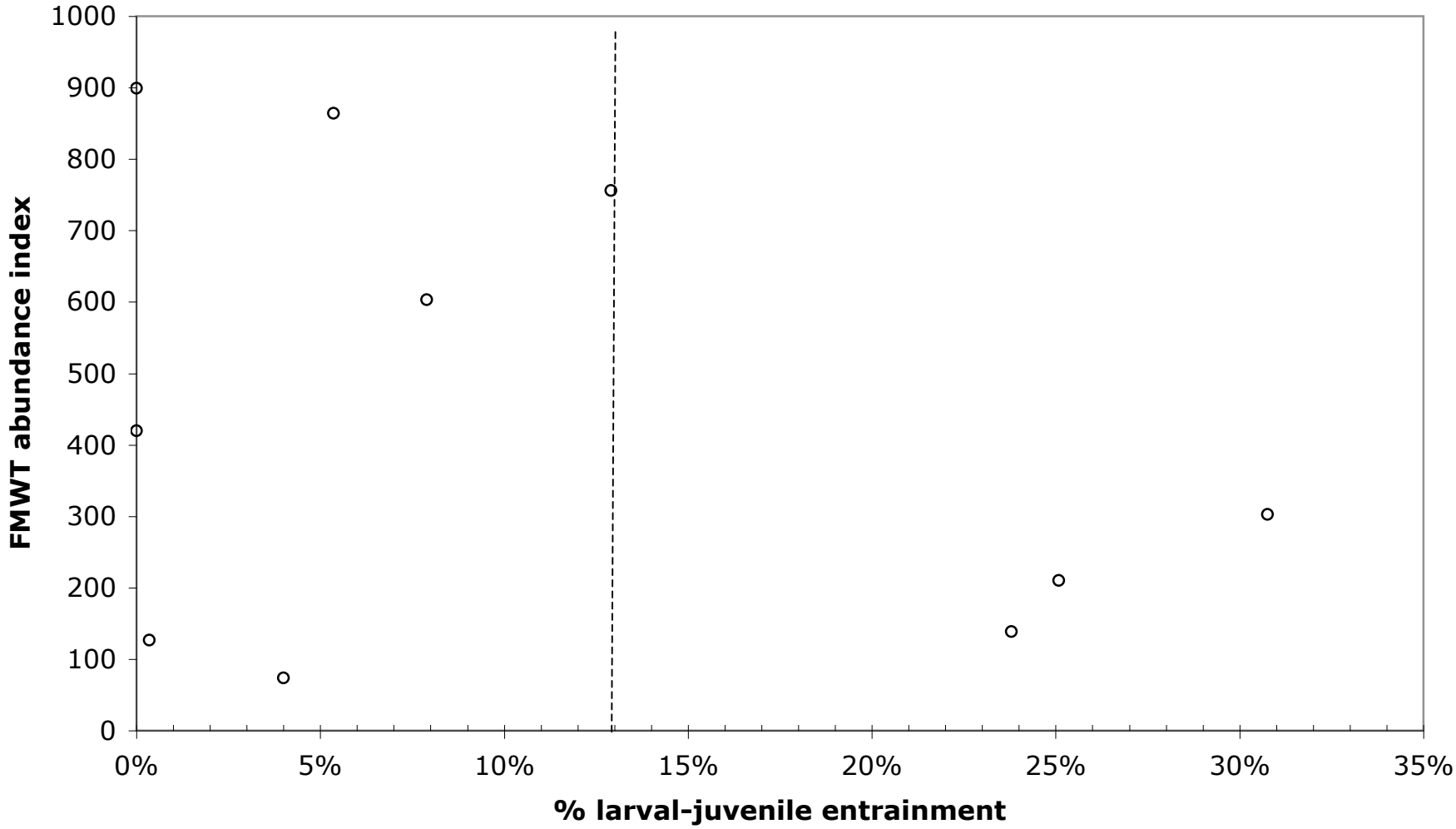


**Figure 7**
**FMWT index vs. % larval-juvenile entrainment**



| Table 1<br>approximate distribution of adult smelt salvage by month 1994-2005 | |
|---|---|
| month | percentage of total adult salvage |
| Nov | 0% |
| Dec | 10% |
| Jan | 40% |
| Feb | 25% |
| Mar | 20% |
| Apr | 5% |
| May | 0% |

# References

Miller 2005a, William J. (BJ) Miller, Estimating the percentage of adult delta smelt entrained at the Banks and Tracy Pumping Plants, paper prepared for the December 2005 workshop on the Environmental Water Account, November 2005

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Miller 2005e, William J (BJ) Miller, Relationships among abundance indices and other important factors, paper prepared for the December 2005 workshop on the Environmental Water Account, November 2005

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